Meeting Report from the Facilities Subcommittee of the National Science Foundation Business and Operations Advisory Committee

Meeting of March 25, 2005 Arlington, VA

Revised Report
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Table of Contents

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Executive Summary

The Facilities Subcommittee of the National Science Foundation's Business and Operations Advisory Committee held its first meeting on March 25, 2005 at NSF headquarters in Arlington Virginia. The Agenda for the meeting is included as Appendix A. The purpose of this meeting was to brief the subcommittee on the facilities issues as viewed by NSF and to begin organizing the work of the subcommittee. All five members, listed in Appendix B, attended this meeting.

The talks shown in the Agenda were presented as listed and were accompanied by vigorous discussion and commentary by subcommittee members as well as by NSF officers attending the meeting. Underlying the purpose of the meeting and acting a source of topical issues was the 2004 National Academies (NA) Report, *"Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation"* commissioned by the House and Senate of the U.S. Congress, together with the October 2004 response to the National Academies (NA) Report by NSF also titled, *"Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation"* and the July 2003 NSF policy document, *"National Science Foundation Facilities Management and Oversight Guide"*. From these documents and the decision of the parent NSF Business and Operations Committee to create the subcommittee, it became clear that the purpose of the subcommittee would be to assess the interaction of these three policy documents with the actual functioning processes of the NSF as the Foundation carries out the assessment, approval, funding and oversight of the large initiatives undertaken as "Major Research Equipment and Facilities Construction" (MREFC) projects.

The expertise of the subcommittee is concentrated in the project management and oversight areas and these are the areas in which the subcommittee feels it can provide most value to NSF. Accordingly, we will concentrate on the project preparation and management aspects of the NA Report issues, leaving questions concerning establishment of scientific priorities and their priority ranking to others. Specifically, the subcommittee intends, in this first report, to focus on the process by which reliable baseline cost and schedule estimates, as well as project management plans, are arrived at for MREFC projects during the "Development" phase and provide commentary on how the reliability of the results can be improved. We also note that the success of MREFC project preparation and management within the NSF is closely tied to the role and activities of the NSF's "Deputy for Large Facility Projects" (DLFP), and we provide some discussion and commentary on this important position as well.

Before providing our conclusions and comments about potential improvements in the MREFC planning and development process, we wish to compliment NSF management on their prompt and constructive response to the NA Report. The positive position taken by the agency is epitomized in a quote from the October 2004 NSF response to the National Academies Report: "The Report includes a number of recommendations by the Study Committee for actions by NSF to address these concerns. NSF embraces the spirit of the Report's recommendations. In this

response, we address the principles of the primary recommendations, leaving the detailed mechanisms to be addressed in consultation with our communities, OMB and Congress."

After examining the three documents noted, discussing the current status of implementation with NSF management and applying our own assessment of the MREFC project management status at the Foundation, the subcommittee provides the following four observations:

1. *The implementation of adequate project management methods for MREFC projects during the Development Stage seriously lags the National Academies Report recommendations as well as NSF policy guidance currently provided for MREFC projects; accordingly, the needed 'Baseline Project Definitions' have not been achieved with adequate reliability as projects move towards New Project status and are submitted by NSF to Congress for funding.*
2. *The failure of NSF to regularly achieve adequate Baseline Project Definitions during the Development Stage is closely tied to the agency's under-investment in professional engineering, cost estimating and project management support for projects during this period; a useful guideline for the necessary level of pre-project engineering/project-management investment is between 10% and 25% of the total project cost to provide reliable cost and schedule estimates at this stage. Currently, NSF notes that large facility projects invest, on-average, only 11.2% of total project cost in MREFC projects (the range is from 2.7% to 22.1%).*
3. *The Deputy for Large Facilities Projects at NSF is a properly conceived role but one that has not been adequately empowered, staffed and supported within the agency to this point in time; a strengthening of the Deputy position, together with a modest-size staff addition of three to five upper-level professionals with project management skills, is needed to realize the purposes recommended in the National Academies Report and accepted by the Foundation.*
4. *NSF would also be well-served by establishing a more specific timeline for implementing the National Academy recommendations; as such, it would be appropriate for NSF to incorporate a summary of actions to date and those planned for the large facilities management process into its annual Performance and Accountability Report and in the Budget Justification to Congress.*

We also provide extended commentary, including specific recommendations, that the subcommittee feels will improve the effectiveness of the NSF's *Facilities Management and Oversight Guide* and help this important internal management document achieve better congruence with the policy intent of the Foundation in its response to the National Academies Report. In a similar vein, we provide commentary, also with specific recommendations, on the topics of planning for the operations and upgrade/closeout MREFC project phases and for project management training of agency and awardee personnel as they prepare for and carry out these projects.

The Subcommittee provides its supporting discussion and commentary in the topical sections below and concurs unanimously in the content of this report.

Main Report

1.0 Relationship of This Report to the National Academies Report and NSF Responses:

General Comments – The discussion and comments of this B&O Subcommittee relate to the 2004 National Academies (NA) Report, *"Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation"* commissioned by the House and Senate of the U.S. Congress, the October 14, 2004 response to the NA report by NSF also titled, *"Setting Priorities for Large Research Facility Projects Supported by the National Science Foundation"* and the July 2003 NSF policy document, *"National Science Foundation Facilities Management and Oversight Guide"*. The NA report made five major recommendations to NSF and the agency responded that they accepted these recommendations and would implement them. In our B&O subcommittee report, we focus on the issues addressed in NA Recommendation 3 (project planning and management aspects of the MREFC process), particularly noting the pressing need for significant improvement of the cost and schedule estimates established for MREFC projects prior to their NSF submission to the Science Board for final approval and to the U.S. Congress for funding. The other four NA recommendations pertain to NSF scientific assessment, priority-setting, inter-agency coordination and road-mapping. We do not discuss these topics in this report, except to note that in Recommendation 1, the NA again characterizes potential new project starts for the near term (0-10 years) as expected to be "well-defined" prior to introduction into the MREFC category.

National Academies Report Recommendation 3 comprises:

> *"To ensure that a large research facility project selected for funding is executed properly, on schedule, and within its budget, the National Science Foundation should enhance project preapproval planning and budgeting to develop a clear understanding of the project's "technical definition" (also called "scope of work") and the "implementation plan" needed to carry out the work.*
>
> *Once a project is funded, there should be provision for a disciplined periodic independent review of the project's progress relative to the original plan by a committee that includes internal and external engineering and construction experts and scientific experts and that will monitor the project's status and provide its evaluation to the NSB and NSF.*
>
> *After the construction phase, a committee with a different external and internal membership that includes scientists and people with experience in managing large facilities should monitor facility operations annually (or as needed).*
>
> *Finally, NSF has created a new position – Deputy Director, Large facility Projects in NSF's Office of Budget, Finance, and Award Management – to oversee the construction of these projects. Given the new nature and importance of this position, it should be reviewed by a committee of internal and external experts to evaluate its operation and effectiveness within a 2-year period."*

The subcommittee concurs fully with NA Recommendation 3. In our report, we explore and comment on the plans of the NSF to implement this recommendation successfully. Of all the topics addressed in Recommendation 3, the subcommittee believes that *NSF most urgently needs to improve its ability to provide reliable cost and schedule estimates directly connected to a clear*

understanding of each project's technical scope prior to NSF approval for MREFC funding. The NSF understands the need to improve its process for achieving reliable cost and schedule estimates and has published the "*National Science Foundation Facilities Management and Oversight Guide"* to characterize the agency's process guidelines for MREFC project proposals and NSF program staff. The date of the *Guide* is July 31, 2003 and the NA report is November 2004. Not surprisingly, the *Guide* in its present form is not completely congruent with all aspects of Recommendation 3. We comment on the 2003 version of the *Guide* in this section, including subcommittee observations about how it might be improved.

The subcommittee also notes the comments in Recommendation 3 related to the position of Deputy Director, Large Facility Projects (DLFP). This is an essential position to champion effective pre-project planning and project delivery, and to provide effective management of the MREFC project process in the NSF, from start to finish and across the agency. We provide our comments about this key position with *observations about how the DLFP position can be made more effective* in a later section of this report.

We next comment on the NSF *Facilities Management and Oversight Guide*, the agency document that provides policy, requirements and procedures for both NSF officers and for MREFC proposers/awardees to follow for considering, approving and carrying out MREFC projects from conception thorough project execution, ensuing facility operations and facility upgrade, renewal or closeout after the initial operations period is complete.

The existence of the *Guide* is a valuable achievement of the agency. It is stated to be a living document and is expected to be periodically updated to reflect the evolving policies of the agency as it addressees the MREFC component of the national science and engineering communities research needs. In its current form, the *Guide* notes the principles that have been captured in the NA Report Recommendation 3, but the subcommittee believes that full implementation of the *Guide* across the agency has lagged the document's prescriptions. For example, the Guide prescribes (p25) that a "Baseline Project Definition" document be produced during the Development stage that precedes the NSF submission of an MREFC project to the NSB and Congress. This requirement includes language that "…*final* cost, schedule and performance baselines are established" [emphasis in the original] for the project. Actual baseline preparation performance in the MREFC projects submitted to the NSB and to the Congress in recent years has fallen short of this requirement, resulting in embarrassing cost growth after submission for funding. Likewise, the *Guide* notes the importance of the NSF Program Officer as the principal manager and overseer of the MREFC project in the agency (p12, p13, p19, p34 and elsewhere) and the Deputy for Large Facility Projects (p5, p12, p14, p19, p34, p40, and elsewhere) as a key provider of management expertise, project experience and project oversight consistency across the agency. The Deputy is expected to work collaboratively with MREFC Program Officers to ensure an NSF-wide quality standard in applying project policy and principles across the agency. The *Guide*, however, is not completely clear about the authority of the Deputy, or the level of responsibility vested by NSF in this position. Again, actual practice in the agency appears to fall short of the expectations articulated in the *Guide*. We provide subcommittee views as to why this is the case here. The *Guide* also makes reference on page 4 to the use of "strong project management" for performing large NSF projects. This is clearly the best way to approach such undertakings. The strong project manager is empowered with many tools to better enable him/her to lead a project team to a successful outcome. However, beyond this one reference to a strong project manager approach, the subcommittee could find no elaboration or description of what the NSF really intended by using this very significant project management term here. Perhaps some elaboration in the *Guide* is called for.

We also note a few points that relate to the *Guide's* stated purpose and supply them here, with the idea that our observations may be considered by NSF for the next *Guide* version released. First, the 2003 version of the *Guide* (p4) indicated that "Large Facility Project Modules" were expected to be ready for use by Fall 2003. These specific Modules will be needed for carrying out large projects but the subcommittee does not know when they will be made public. We were informed by NSF, that five modules have been posted in draft form on internal NSF websites and two more are in the development phase. We encourage the completion, acceptance and release of these needed modules as soon as reasonably possible. Second, a plan was conveyed to the subcommittee by NSF at the March 25, 2005 Meeting, indicating that NSF intended to prepare a companion document to the internal NSF *Guide*, to be used by *Awardees* in carrying out NSF MREFC projects. This is an essential step. Such a document should be much more prescriptive than the *Guide* and should describe in detail, form and content, the documents required to support each decision requested of NSF. Third, we note that, in the *Guide*, the only apparent entry ramp for collaborations is in the Development Stage. This is nicely defined with a MOU process. Clearly, collaborations have been formed beyond this stage in the past and this aspect is desirable to preserve. There should be explicit opportunities for private and international collaborators at every stage in the process and these should be spelled out in the *Guide*. For example, bringing in additional collaborators as an explicit alternative to reducing the scope of the project during the design phase if cost growth is encountered; or, more creatively, encouraging private partners to fund final design work for the Conceptual Design Report while awaiting funding after NSB approval. This can have a significant effect on progress by speeding up schedule with attendant cost savings.

2.0 NSF Planning Stages - Relationship to NSF and Science Community:

The NSF and National Science Board, together, have described a number of pre-project planning and preparation stages for MREFC candidate projects in their response to the *"Setting Priorities for Large Facility Projects Supported by the National Science Foundation."* The stages commence with the "Horizon Stage", followed by the "Concept Stage", "Development Stage", "Readiness Stage", "Candidate for New Start" and "New Start" stages. These stages are followed by the NSF's budget proposal to the U.S. Congress for MREFC funding. Our comments in this section are preceded by brief explications of the NSF categories. We conclude this section with some general observations and comments germane to the defined NSF/NSB project stages.

H*orizon Stage* – This stage is defined in *Setting Priorities* as the point during which a new idea emerges in the science research community that requires a substantial new facility for its realization. Such a new facility need may arise as the community encompasses a 10 to 20 year forward look into its future science program. The NSF program officers and staff are encouraged to be alert to such breakthrough concepts and to actively encourage related thinking and planning. The agency and the various research communities are already quite effective in carrying out this stage of the process and the subcommittee has no specific advice to offer here.

Concept Stage – This stage is defined as the point at which a candidate facility project is proposed for support of development. The NSF's MREFC Panel is fully apprized of projects as they make the transition from Horizon to Concept stage. It is understood that projects in the Concept stage are eligible to be funded by the NSF with R&D funds for refinement of the technological approach (and alternatives) to realize the science. An appropriate part of this process is the holding of ad-hoc community workshops and National Academies' studies as well as research projects for development of new technologies relevant to the concept. Again, the

research communities and the NSF are performing appropriately in supporting this stage and the subcommittee has no specific advice here.

Development Stage – This stage is defined as the point at which a candidate project matures into more formal planning by the agency. Once entered into the development stage, projects are tracked and their status reported on a regular basis to the NSF's MREFC Panel. The NSF *Facility Plan* will provide periodic updates on each development project to the Science Board. At this point, each project will generate its own *Project Development Plan*, collaboratively prepared by project and NSF program staff. As noted in the NSF *Setting Priorities* document, *"The Development Plan, updated regularly, will lay out the necessary technical, logistical, and financial trajectory of the project, including decision points, needed to ready the project for construction consideration. The Development Plan will also identify long-lead items at the appropriate stage and should set out strategies to minimize possible gaps in support as planning matures."* This policy guideline is sound and appropriate but its practical realization is lagging in the MREFC projects at the Development Stage. In fact, the cost and schedule information developed by the projects often lacks rigor and reviewers of MREFC project estimates have typically failed to apply evaluation standards that ensure predictable and reliable outcomes. The result has been periodic public uproars over projected costs that embarrass the Foundation and undercut the credibility of the MREFC process. The subcommittee feels this topic is important enough to warrant its own report section and discussion below.

Readiness Stage – This stage is defined as the point at which a small group of projects in the advanced stages of development are ready to go to the Science Board for approval as MREFC projects. To meet the conditions for achieving this stage, the successful projects must meet the NSF *Setting Priorities* criteria: "*Readiness is defined in terms of a clearly defined science program, sufficiently mature engineering design and construction plans, plans for operation subsequent to construction, budget projections, and late stage evaluation of the proposed project by the research community and within the NSF."* Again, this policy statement provides appropriate criteria for advancing MREFC projects to the Science Board for approval and potential submission to Congress by NSF for a funding start, but this standard has not been well met historically. NSF notes that projects can fall from the Readiness List for any number of reasons, so attaining a position on the Readiness List is an important achievement but does not assure that the project will succeed. We note that the *Readiness* conditions have routinely not been met by actual MREFC projects submitted to Congress and our comments in the section below on cost and schedule preparation are appropriate to both the development and readiness stages.

New Start Candidate Stage – This stage is defined as the point at which a 'Readiness Stage' project is selected by the NSF MREFC Panel and the Director as appropriate to go to the NSB for approval and inclusion in the "Candidate for New Start" pool of NSB approved projects. Any project that is recommended to the Board for approval will be expected to have achieved its project-specific goals, as laid out in its development plan. An important criterion is that the new start candidate have clearly articulated the costs of operation and maintenance; these costs are not covered in the MREFC funding.

New Start Stage – This stage is defined as the point at which the NSB has approved the New Start. The NSF Director will annually propose funding for some subset of the Board-approved New Start pool of projects in their priority order and negotiate this list with the Office of Management and Budget prior to submission to Congress as part of the President's Budget for that year.

General Observations on Project Stages – The subcommittee felt that the definition of six stages of planning and preparation prior to the receipt of funding from Congress may have value to the agency and to the Science Board, but some of these stages and their titles are not generally used in the wider project communities. For this reason, it may have value to group these new titles as conceptually useful subcategories under the more conventionally used Planning, Development and Implementation category titles. The subcommittee would group the Horizon and Concept stages under the Planning label and the Development, Readiness, New Start Candidate and New Start stages under the Development label. If such an approach is taken, stakeholders outside the NSF and NSB will be familiar with the basis for the NSF stages and can pursue use of the subcategory titles within their NSF context as needed. We also note that it would be valuable for MREFC projects to have an optimum formula for the number and average dwell time for new projects in the each of the various pre-construction approval stages.

In addition to these categorical observations, we note that, in the scheme where the project's home Directorate budget must fund everything except the actual construction phase of the project, careful attention must be paid to the "hand-off" at both ends to assure smooth transition in funding and management, as well as complete buy-in by all the project partners involved. This includes the funding, completion and review of the baseline design, agreement on the scope and the funding of pre-ops, as well as full planning for the operations and upgrade or closeout periods. To the extent that the start of construction brings new players into the picture, it is essential to ensure that there is acceptance on all sides (NSF, grantee institution, and the team that led the baseline design, plus the new players) of the way forward for the overall budget, timelines, etc.

3.0 Cost and Schedule Preparation in the Development Phase:

As noted earlier in this report, the subcommittee feels that a key area for improvement of the NSF process for approving MREFC projects is the preparation of credible scope, cost and schedule estimates for the projects during the Development Stage and prior to their presentation to the Science Board for approval to submit to Congress for funding. Given the difficult history of these estimates in the past, the subcommittee advocates a *prescriptive* rather than advisory statement of policy to the proposing groups and NSF Program Officers. Specifically, before a candidate project can be admitted to the MREFC category as a new start, we believe it needs to have produced the following list of credible project characterization items:

- Scientific Mission Statement
- Collaboration List
- Scientific Requirements Specifications
- Project Scope
- Proposed or Preferred Site or Sites
- Draft Environmental Assessment/Impact Statement
- Complete Work Breakdown Structure (WBS) with a Dictionary
- WBS-based Cost Estimate with a Bottoms-up Contingency Estimate tied to the Risk Analysis
- Resource-Loaded Project Schedule with identified Critical Path
- Project Funding Profile
- R&D Requirements, Development Plan and Risk Analysis

The subcommittee is keenly aware that this list of items cannot be created without the investment of substantial amounts of development funding. In typical one-of-a-kind facilities, it may require investing between 10% and 25% of the total project cost to perform the required planning, R&D

and preliminary engineering to meet this list of requirements. Currently, NSF notes that large facility projects invest, on-average, only 11.2% of total project cost in MREFC projects (the range is from 2.7% to 22.1%). How the NSF will decide to apportion the funding is an agency policy issue that we do not address but it will not be possible to improve the record in this area without making bigger planning investments for MREFC candidate projects.

Within the Development Stage for projects that involve new construction at a project site, the above includes a set of relatively large time and cost consuming activities that must be dealt with. These involve an Environmental Assessment (EA) or Environmental Impact Statement (EIS), plus Mitigation Measures that pertain to the prospective site. All the resulting site-specific issues and permits, with their mitigation measures, need to be addressed. The site selection and the EA/EIS can be initiated during the preliminary design period and processed concurrently with the development of the final design documents. In doing so, the estimated cost of the new work will improve in quality as the scope of mitigation measures and their costs become better defined. If a full EIS process is required, it will take 18 to 24 months to complete and, at completion, will yield the necessary mitigating measures and the Record of Decision required for the start of construction. Likewise, the authorization through the MREFC account can be progressing in parallel, reducing the overall time duration and cost of the project.

Other cost issues are noted here. The procedural path that each project must follow to get to the point where it can realistically plan for start of MREFC funding is a long one. The escalation costs, alone, of these multi-year process times are significant. Loss of the skills and experience of key project team members to other, nearer opportunities is also a significant cost. Project cost estimates prepared during the Development Stage suffer from a number of influences that result in estimated values that are both unreliable and difficult to defend. The two suggestions above can help with this problem. But there is more that can be done. The risks identified years before a project moves forward, and cost-estimated at that time, are seldom well-understood and, therefore, seldom well-represented in the contingency allowed. Escalation of the projected cost of labor and materials for construction can be little more than a guess, when looking out five years or more. Escalation guidelines are provided and regularly updated by the U.S. Government and should be made available to and used by project development teams. Finally, the construction cost estimates on which the MREFC funding is based should be as representative of the final cost as can reasonably be made, incorporating the escalation basis just noted. For best results, it should be based on a mid-point-of-construction based cost estimate, with that date estimated by the NSF Program Officer to reflect current experience in the Foundation with waiting times in the MREFC queue.

4.0 Planning for the Operations and Upgrade/Closeout Phases:

However it is to be accomplished, the facility operations and facility upgrade or closeout phases must be planned for, scoped, cost-estimated, budgeted, and processed in a timely manner through the NSF's funding mechanisms to provide the necessary personnel and skill resources to be able to fully realize the potential of each new scientific instrument added to the Nation's resources. These 'cradle-to-grave' budgeting concepts have now been recognized as necessary in the top NSF management forums and the *"NSF Facilities and Management & Oversight Guide"* countenances their use. The subcommittee supports this development and provides the comments above on a few subsidiary issues that appeared to be less than clearly addressed in the *Guide*. The subcommittee next provides some detailed comments on additional topics associated with the operations phase of an MREFC project, followed by some comments on the facility closeout phase.

An important topic for the NSF in the MREFC projects is the role of budgeting policy between the *construction* and the *operations* phases of these projects. The two phases are not funded from the same accounts, so the categorical distinctions and cost accounting procedures are of great interest to the involved directorates as well as to the Foundation's top management. The subcommittee notes the sensitivity in the agency to these categorical distinctions and provides some comments on this topic. To begin with, we note that in the NSF Facilities and Management & Oversight Guide, Section IV, Part B – Budgeting and Funding, (Pg 41), the fifth paragraph makes a very clear distinction regarding funding sources which may flow to Awardees during the lifecycle of a project/facility. It says:

> *"In general, Awardees are funded through the MREFC, R&RA and/or EHR accounts. When funds from these separate appropriations are obligated under a single award, the award instrument must include provisions that specify the account to which expenditures are to be charged and restrict any reprogramming of funds by the Awardee (NSF Bulletin 01-15, July 3, 2001). In all cases, attention must be paid to the fundamental difference between building the basic infrastructure --- i.e., constructing and or acquiring the facility and all its installed instrumentation and equipment --- and enabling others to use the infrastructure once it has been established. "Enabling" is typically done through grants, funded by NSF through the R&RA and/or EHR accounts and/or other agencies, to individual researchers to conduct research at the facility."*

By implication, the "constructing and/or acquiring the facility and all its installed instrumentation and equipment" for a MREFC project, will be accomplished through funding under the MREFC account. "Construction and/or acquisition" (C&A) as a defining point seems to have been chosen here (and also in Section IIC2, page 18) with the intent of providing a clearly recognized point in a program's evolution when the source of funding changes from R&D work under an R&RA account, to MREFC funds for construction (and later back to R&RA or EHS for operations). It is stated that there shall be no mingling of funds from either the R&D or EHS accounts with MREFC funds. However, continuing R&D work, community research program planning, User Committees, or other such appropriate activities can and do continue in parallel with the MREFC activity. These non-construction activities continue to employ R&RA or EHS account funds but with careful controls and accounting to assure that there is no mingling of funds. Does this then allow work products flowing from these R&D/EHS activities to flow to the MREFC project team? It may be useful to note in the Guide that R&D/EHS work products may be transferred to MREFC use, provided appropriate aspects of the transferred work is charged to the MREFC project account.

A related, but perhaps more difficult to separate period in the life of a project, is likely to occur when the facility is reaching the end of construction and some of the unique equipment to be utilized in the new facility has been installed. It is common in new science facilities work for user access to such equipment to be conditionally granted on the basis of "Joint Occupancy" (JO) by the users and the MREFC project team. This JO access privilege allows working scientists and technicians to begin familiarizing themselves with the unique equipment and, as more of the operating equipment is installed, for them to begin to perform some preliminary operations with it. The JO work is taking place in a project facility that has not yet been fully tested, evaluated and accepted (TE&A) and is, therefore, still a construction site — a site being worked under MREFC funds. There is a positive benefit for the project as a whole because the testing and operating that the science team is performing will contribute to the final TE&A for the completed facility. If the user team finds some condition that does not meet the Facility Requirements Specifications, there may be time for that shortcoming to be fixed before it becomes a schedule

issue. This early, partial use of available components of a new facility under construction is often called *Pre-operations or Pre-Ops.* How should such activities be funded?

- Under the NSF funding management model that calls for separation of work type by cost accounts, it might appear that the Pre-Ops activity would have to be planned, budgeted and appropriated under an R&RA account and anticipated years before its occurrence.
- A better alternative would be to explicitly provide some planned Pre-Ops activity for facility operations commissioning as a part of the TE&A work under the project's QA/QC Plan. The commissioning period would transition into the R&RA funded operations period when the defined set of operating conditions had been demonstrated. All such work could then, appropriately, be included within the scope of the MREFC account.
- A final alternative would be to plan, budget, fund and authorize the New Facility Operations to begin concurrently with the on-going construction and procurement, with this work being devoted exclusively to commissioning operations on the new equipment.

The first and third alternatives end up charging the R&RA accounts with activities that the second would place in the MREFC scope. At the present time, it appears to the subcommittee that the NSF favors the approach in the second bullet and the subcommittee supports this alternative as the most effective, rational and justified of the alternatives.

The initiation of MREFC projects often originates from institutions and collaborating groups with ongoing funding from NSF under R&RA accounts. NSF Centers of Excellence, such as NOAO, NSO, NRAO and others are likely to be among these. Each of these centers receives its annual operating funding through a Cooperative Agreement and each employs a core group of scientific, engineering and technical staff members, along with research and production equipment suitable for its mission. As one of these organizations conceives and develops a plan for a new, state-of-the-art science facility, core staff members are often deeply involved in creating the technical concepts and design documents that support the MREFC project. The staff members usually work on the new project right through the Implementation Stage. Concurrent participation by staff members funded under an NSF operations account during the Implementation Stage (funded under the MREFC account) may be thought to constitute a possible violation of the separation of function and funding cited earlier. It is certainly typical that the core New Project Team will come from the resident staff. Their effort charges can easily be transferred to the new MREFC account as soon as it is activated. These individuals are usually supported and assisted by a large number of people who are also employees of the organization. The requirements for these support services providers are such that they are only needed part time. The expertise of the support staff is, though part-time, is nonetheless badly needed since they carry the institutional memory for the New Project, acquired over the many years of the project's gestation through the NSF processes. Split time-sheet effort reporting should be provided for such persons. And finally, there are those who contributed to advancing the project for years and might continue to do so by force of habit as much as by assignment, but they may not record their time for the project because they are not directed to do so. Such persons could become a source of "contributed services". The subcommittee recognizes all these forms of staff support and believes that their efforts can be properly assigned and accounted within the funding rules of NSF.

All MREFC facilities have a finite lifetime during which they are scientifically competitive without major renovations. When a facility and its science program are planned there should be an estimate of the competitive lifetime, based on the science program and the past experience with related facilities. A closeout plan addressing the end of operations phase should be a required part of the MREFC process, even if the time frame and ultimate disposition of the

facility is not clear at the time of initiation. The plan could take the form of several alternate scenarios such as privatization, repurposing, or decommissioning and disposal. Environmental constraints will be an important part of the closeout plan. Addressing closeout scenarios during the design process will impact the total lifetime costs of NSF MREFC projects but could affect the technical design in such a way as to favorably influence overall costs.

5.0 Role of the Deputy for Large Facility Projects:

The role of the Deputy Large Facility Projects (DLFP) needs to be clarified and strengthened. The role as set forth in NSF's *Facilities Management and Oversight Guide* and in the response to the National Academies Report is not sufficiently clear, nor strongly enough stated, to expect the DLFP to be a major "difference maker" in project performance. Although the DLFP reports high up in the NSF and is charged with important responsibilities, this position presently seems to lack the proper level of authority to carry out its intended mission. Furthermore, with only a single person on-staff in this role, there is also a manifest inability to adequately track all the MREFC projects and thereby contribute to better outcomes in the intended way. By way of emphasizing the need for strengthening the DLFP role, including its staffing, we note the commentary made about this position in the National Academies Report (p42):

> *"NSF's deputy for large facility projects needs adequate staff and institutional authority to assure the NSF leadership and the NSB that proper project management is in place for each project and that work is progressing on schedule and within budget. Each project will have dedicated leadership, but the deputy for large facility projects has principal responsibility to support the undertakings and for oversight and management. In particular, NSF is encouraged to review the model of large facility project management and oversight that DOE's Office of Science uses through its dedicated Construction Management and Support Division [now, Office of Project Assessment]. That division [Office], although serving a larger community, has been successful in balancing the uncertainties of predicting the challenges of building unique experimental facilities and the need for responsible project planning, management, and review."*

The line responsibility and authority for oversight and execution of an MREFC project rests with the NSF program directorates. The DLFP has an advisory oversight role for all facility projects, reporting to the Chief Financial Officer and to the Foundation Director. The ability of the DLFP to provide effective advice to management on any given project will be strongly influenced by a number of factors, namely, the ability to: convey relevant experience and successful management methods from other MREFC projects at NSF; articulate the level of involvement and understanding of the challenges and issues for each specific MREFC project; embody a clear means to impact facility project decision making at the NSF thorough comprehensive knowledge across the entire MREFC program. The DLFP should be a major player throughout the entire lifecycle of every facility project and have the ear of top NSF management on the health and status of all the components of this program. This role should include the Development Stage when many decisions are being made that will have a major impact on the opportunity for success during the Implementation Stage. During the Development Stage, the management arrangements, procurement strategies, cost and schedule baselines, contingency and risk management strategies are decided. There are many pitfalls that can be avoided with the timely involvement of skilled and experienced people to advise project teams. The DLFP appears to be expected to provide this service to every MREFC project team. In its present implementation, the DLFP is not sufficiently empowered to carry out this mission and our subcommittee questions the full commitment of the agency to its success as propounded above. We note that in the NSF's *Facilities Management & Oversight Guide*, the DLFP position is mentioned only 12 times in a

52-page document, with a varying spectrum of intended roles and powers. We imagine that the characterization of the DLFP position was evolving together with the writing of the Guide itself, leading to the diversity of position descriptions. The *Guide* should be amended to clarify and strengthen the DLFP role and position if the NSF expects to have the benefit of improved MREFC project performance as intended.

The DLFP cannot be expected to affect significant improvements in overall project performance if he or she is limited to making suggestions and offering recommendations. Large dollar, multi-year, complex construction and procurement projects represent great opportunities as well as serious risk exposure for the Foundation. The NSF should look to the DLFP to provide strong and reliable guidance and advice to the directorates, their staffs and to the awardees with regard to MREFC project execution, as well as provide expert advice and guidance on evolution of the entire suite of MREFC projects to top Foundation management. It is understood that changing the way the organization conducts business, specifically the introduction of a new player, will take some time. The DLFP must be given the opportunity to demonstrate the value of this advice and guidance for improving the likelihood of successful project delivery. The DLFP, in turn, must be empowered with sufficient resources to be able to provide constructive inputs to project teams and develop a trust relationship with key NSF staff. A strengthening of the Deputy position, together with a modest-size staff addition of three to five upper-level professionals with project management skills, is needed to realize the purposes recommended in the National Academies Report and accepted by the Foundation.

As noted in the NA Report quoted above, a relevant example for the DLFP is the role of Office of Project Assessment (SC-1.3) in the Department of Energy's Office of Science. The PA Director (PAD), Mr. Daniel Lehman, oversees a staff of 4 persons and reports directly to the Director of the Office of Science. The PAD provides independent advice to the Director on those activities essential to constructing and operating major research facilities, currently, about 31 construction projects varying in total cost from $5M to $1400M. This is larger than but roughly comparable to the NSF's total MREFC scope. In addition, the PA Office provides professional management and staff support for these functions to program offices. The Office of Project Assessment has evolved over twenty years into a major organization player that has helped to improve project performance in the Office of Science of the Department of Energy. The major activity of the Office comprises the organization of periodic project reviews, commissioned by the Associate Directors of the Office of Science and staffed by panels of expert peers not directly involved with the project but knowledgeable about the science and facilities issues involved. The reviewed project managers have received significant advice and effective guidance in completing their missions from these reviews. A "Lehman Review" has real meaning throughout the Office of Science for major facility projects. A report from a Lehman Review that is strongly critical of the way a project is organized, led, or performed will typically lead to early corrective action by the Office of Science. A similar role for the DLFP, appropriately modified for the culture of the Foundation, could be expected to yield similar value for NSF. The subcommittee next offers some comments on how the DLFP role could evolve and improve in this regard.

Following this model and consistent with the NSF *Guide's* characterization of this role, the DLFP, working closely with the NSF program directorates, would be responsible for ensuring that periodic reviews of MREFC projects are properly commissioned, charged and carried out by well-chosen expert reviewers. The DLFP would be responsible for ensuring that the review agenda and panel membership is appropriate to the purpose as well as for maintaining NSF-wide standards for review quality and content across the directorates. The DLFP should ensure that each review results in a written report containing findings, comments and (as needed)

recommendations. The responsible program directorate and the performing awardee organization would be required to respond to the review report. The frequency of reviews would follow an annual or semi-annual pattern as appropriate to the project, but reviews on an ad-hoc basis could be held as needed to respond to time-critical project issues.

As preparation for the initiation of a standard MREFC project review program, including close cooperation of the Program Officer and the DLFP, NSF policy guidance documents should be strengthened to include common standards and expectations for the management of all MREFC projects. These policy documents will need to move from a 'suggestive' mode to a more 'prescriptive' mode if the desired Foundation-wide improvements are to be achieved. One of the most valuable benefits that will accrue to NSF under this strengthened system will be the utilization of the DLFP's expertise across the entire Foundation's project portfolio, embodying the experience and expertise that the DLFP can offer to new MREFC managers. The Project Documentation for each project should have a form that is sufficiently consistent within NSF to enable a common understanding by all stakeholders of the value of this documentation and the significance of the information provided.

6.0 Project Management Training and Skill Development:

It is clear that those science projects that will pass through the MREFC accounts will be significant undertakings, by any standards applied. They are more likely to be highly complex projects, dollar for dollar, than conventional construction projects of similar cost. They will typically be carried out over a time period of five or more years and will be budgeted at more than $100M. They will be highly complex scientifically and technically and perhaps organizationally. They may well involve multiple and/or non-domestic U.S. working sites, and they may involve unusual partnerships or global arrangements. Where global or multinational partnerships and agreements are involved, as would seem to be the NSF expectation from page 22 of the *Guide*, international project operations, funding and management experience as well as cultural sensitivity and language skills may be required. In the realm of Project Management, this combination of conditions, constraints and challenges would qualify these projects as *complex mega-projects.* Thus the Project Managers selected to manage and execute such projects should be very skilled and experienced in project management and possess the additional special skills necessary for each situation. (For additional useful information, see "Characteristics of Successful Megaprojects", NRC 2000, Gilbert et al)

The NSF Program Officer (PO) and the project Awardee's Principal Investigator (PI), both of whom may have nurtured and husbanded the project from an idea through Concept and Development to arrive at Implementation, will generally not be good candidates to become the Project Manager. The Program Officer, as a Foundation officer, is the overseer of the project, not its manager. The PI typically guides the continuing project-related R&D and maintains the relationship of the scientific mission and the scientific collaboration to the project and to the planning and budgeting for pre-operation and operations activities. The Project Management skill set required for successful performance of the Implementation Phase of such projects is not likely be found with either the PO or the PI.

However, some specific formal project management training is appropriate for both the PO and the PI, and could be for others who will have management roles in the MREFC project. It is very important for such persons to gain a good understanding of the vocabulary and discipline of project management and also to learn some of the tools and techniques employed to plan and set up, track, trend and report project performance. The PO and PI should gain a basic capability to

read, evaluate and utilize risk registries, risk analyses and risk pricing as it is used on their project. They should also learn to appreciate the strategy employed to set up the project Work Breakdown Structure (WBS). They must learn how to read, interpret and probe the periodic project performance reports that the project manager will be providing as the project progresses to completion. If the NSF is to meet the expectations of the Congressional Committees as indicated by the inquiry that led to the National Academies report, significant formal project management training, based on a set of approved NSF project management procedures, will be necessary for these important project players.

The DLFP is the acknowledged source of project management expertise within the NSF. But one person cannot embody the needed project management resources for an organization the size and breadth of the NSF, especially with its extensive and growing portfolio of MREFC projects. The DLFP cannot even be expected to function effectively as a mentor to more than a few project managers at any one time. Some additional project management training resources are needed, especially for NSF POs and Awardee PIs of MREFC projects. The subcommittee believes that the project management resource represented by the DLFP needs to be supplemented by project management training of POs and PIs in order to meet the objective of a knowledgeable management of MREFC projects within the NSF

These necessary characteristics and skills can be provided and learned. Topics that should be part of a PM training program include the following:

- Project Manager Roles and Responsibilities
- Project Management Processes
- Project Organizations and Integrated Project Teams
- Pre-Project Planning and Preparation
- Project Scope Management
- Project Time/Schedule Management
- Project Cost—Including Contingency—Management
- Earned Value Management Systems
- Project Quality Management
- Project Human Resources Management
- Project Communications Management
- Project Risk Management
- Project Procurement Management
- Project Lessons Learned

As the project management standards of the Foundation are firmed up and implemented, the recommended training can be modularized and made available on the web as well as taught in typical classroom settings at the Foundation and (as needed) at Awardee sites. Some of these modules may be obtained and used directly from the Project Management Institute (PMI).

The subcommittee notes that the NSF has provided for NSF staff, a very effective seminar on Project Management topics under the sponsorship of Dr. Gary Sanders of the California Institute of Technology. In particular, the learning-by-experience aspect of this program has been very valuable for promulgating project management skills to science project personnel. First person, hands-on Lessons Learned can be very instructive. The Subcommittee fully supports the sponsorship of such programs for POs and PIs, as well as other project-related persons as appropriate.

Appendix A- Subcommittee Meeting Agenda

Facilities Subcommittee of the BFA Business and Operations Advisory Committee

Room 470

March 25, 2005

8:00 a.m. Welcome and Introductions – Tom Cooley, Director, Office of Budget, Finance and Award Management, and NSF Chief Financial Officer (10 min)

8:10 a.m. Remarks – Tom Kirk, Subcommittee Chair (10 min)

Morning theme: Context overview – NRC report recommendations for facility oversight, as these relate to existing NSF policies and processes; NSF support and commitment to the NRC recommendations.

8:20 a.m. MREFC facilities development process– Mark Coles, Deputy Director, Large Facility Projects, Office of Budget, Finance, and Award Management (90 min)

- MREFC account history
- NSF and NSB roles, MREFC panel
- Overview of NAS report recommendations
- External focus: NSF's traditional communication with external stakeholders
- Internal focus: Interactions between BFA and Program staff in project development and oversight
- Role of NSB and Congress in MREFC development process
- Process for MREFC baseline development and project evolution
  - Science objectives
  - Development of NSF's internal plans and processes
  - Project technical, cost and schedule development

(Includes time for Q&A)

10:00 a.m. Break

10:15 a.m. Facilities Guide concepts: - Patti McNamara, Senior Facilities Advisor, Office of Budget, Finance, and Award Management (30 minutes + 30 minutes Q&A)

Discussion of relevant Facilities Management and Oversight Guide topics: [Note: the NSF Facilities Management and Oversight Guide is available at http://www.nsf.gov/pubs/2003/nsf03049/nsf03049.pdf]

- Guide addresses both internal and external audiences
- Description of evolution of project maturity prior to construction
- Baseline development is part of construction proposal
- Funding hiatus is built into the MREFC process. How do we get past Catch-22 with baseline?
- Central role of program officer is project oversight
- Not much description of LFP Deputy role – how to clarify?

- Other topics may emerge from discussion

11:15 a.m. Perspective from DCCA - Donna Fortunat, Director of the Division of Contracts and Complex Agreements (20 minutes)

11:35 Perspective from DGA - Gerry Glaser, Director of the Division of Grants and Agreements (10 minutes)

12:00 p.m. Lunch discussion - NSF Facilities Plan overview – John Hunt

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Afternoon theme: NSF would like the subcommittee to provide feedback on the following question: "How best to convey NSF's expectations to the research community for what a MREFC project needs to do to be considered ready for construction."

1:00 p.m. Community and Congressional expectations – Curt Suplee, Director, Office of Legislative and Public Affairs

1:30 p.m. View from the National Ecological Observatory Network (NEON) - Liz Blood, NEON Program Director, Division of Biological Infrastructure, Biological Sciences Directorate

2:15 p.m. View from the Astronomy Division - Wayne Van Citters, Division Director, Astronomical Sciences, Directorate for Mathematical and Physical Sciences

3:00 p.m. Break

3:15 p.m. Subcommittee discussion

4:30 p.m. Closeout and action items - identify issues to present at B&O Advisory Committee meeting plus Subcommittee assignments for next meeting

5:00 p.m. Adjourn

Appendix B
Members of the Facilities Subcommittee of the NSF B&O Advisory Committee

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